# KHAINGS VIBRATION SURVEY REPORT

Synthetic Compressor 01

DRAFT — prepared by automated analysis, pending analyst review.

ISO ZONE D — UNACCEPTABLE · 1 COMMITTED FINDING

GATE VERDICT: WARN iso_zone_elevated: WARN — ISO zone D Full roster below.

MACHINE

Synthetic Compressor 01 · compressor

DUTY

1800 rpm · ISO group 2 · bearing 6206

DATA

Envelope spectrum · 2000 lines · 500.0 Hz

SEVERITY

## Zone D — unacceptable

5.20 mm/s on y · ISO 20816-3:2022 — Group 2, rigid support

COMMITTED DIAGNOSIS

## Bearing outer-race fault (BPFO)

confidence high · severity danger

### STATUS — ISO ZONE D — UNACCEPTABLE · 1 committed finding

EXECUTIVE SUMMARY

Synthetic Compressor 01 is operating in the danger band under ISO 20816-3 (Group 2, rigid support). The committed diagnosis is a **bearing outer-race fault (BPFO)** assessed with **high confidence** against bearing model 6206. The dominant radial peak at 107.25 Hz on the y-axis matches the computed BPFO of 107.03 Hz to within 0.20%, and a 2× harmonic is also present, providing corroborating evidence. Overall vibration severity on the dominant axis is 5.20 mm/s RMS, placing the machine firmly in the danger band. Immediate attention is warranted: the bearing should be scheduled for replacement at the earliest practicable maintenance window, with close monitoring in the interim.

## MACHINE DETAILS

| FIELD | VALUE |
| --- | --- |
| Machine | Synthetic Compressor 01 |
| Type | Compressor |
| Location | — |
| Sensor / MAC | SYN-COMP-01 |
| ISO group / support | 2 / rigid |
| Running speed | 1800.0 rpm (30.00 Hz shaft rate) |
| Overall vibration | 5.20 mm/s RMS (y-axis dominant) |
| Bearing model | 6206 |

## DATA QUALITY

**Gate verdict: WARN.**

All core validity checks passed (acceleration data validity, machine running, startup transient, spectrum non-flat, clipping, ski-slope, speed sanity). One check requires attention:

- **iso_zone_elevated — WARN:** The ISO 20816-3 severity reading falls in the danger band. This warning is expected given the committed fault; it does not invalidate the spectral data, but findings should be read with the caveat that a data-quality warning is present on this reading.

## SEVERITY & COVERAGE

**What was assessed:** Bearing fault detection was performed via spectral and envelope analysis, matching peaks against computed fault frequencies for the 6206 bearing at 1800 rpm. The BPFO, BPFI, BSF, and FTF families were all computed and evaluated. The dominant finding — BPFO — is supported by both the primary peak and its 2× harmonic.

**Severity rating:** Overall vibration on the dominant (y) axis is **5.20 mm/s RMS**, classified as **danger** under ISO 20816-3:2022, Group 2, rigid support (threshold C/D boundary: 4.5 mm/s). The x-axis (axial) reads 0.50 mm/s and the z-axis reads 4.80 mm/s; the y-axis is the dominant radial axis and governs the severity classification.

**What was not assessed:** No z-score anomaly detection was performed — this requires a streaming baseline, which was not available for this reading. No trend regression was computed, as no historical data series was supplied.

DIAGNOSIS

**Committed diagnosis: Bearing outer-race fault (BPFO) — severity: danger, confidence: high.**

The rank-1 peak on the y-axis at **107.25 Hz** matches the computed BPFO of **107.03 Hz** for the 6206 bearing at 1800 rpm, a deviation of just 0.20% — well within the ±3% match tolerance. The amplitude of this peak (0.36, rank 1 on the y-axis) is the dominant spectral feature on that axis. A **2× BPFO harmonic at 214.25 Hz** (rank 2, amplitude 0.14) is also present, providing independent corroborating evidence of the outer-race defect frequency. The y-axis is the expected radial axis for this bearing configuration, and the fault tone appearing there is consistent with the expected directional pattern for a BPFO excitation.

## Confidence factors

| FACTOR | EFFECT |
|---|---|
| BPFO peak matched on a radial axis | Supporting |
| Bearing tone on the expected radial axis | Supporting |
| BPFO is the dominant (rank-1) peak on y | Supporting |
| Frequency match within 0.20% of computed BPFO | Supporting |
| 2× BPFO harmonic present | Supporting |
| Data-quality warnings present on this reading | Mild negative |

The data-quality warning (iso_zone_elevated) applies a mild negative weight to confidence; however, the weight of the supporting evidence — tight frequency match, rank-1 dominance, harmonic confirmation, and correct axis pattern — is sufficient to sustain a **high** confidence assessment.

## Spectral evidence summary

| FINDING | AXIS | COMPUTED (HZ) | OBSERVED (HZ) | MATCH ERROR | 2× HARMONIC | SIDEBANDS |
|---|---|---|---|---|---|---|
| Bearing outer-race fault (BPFO) | y | 107.03 | 107.25 | 0.20% | Yes (214.25 Hz) | — |

ALSO CONSIDERED

No differential candidates were raised and set aside. The BPFO match was committed directly; no competing fault families produced a frequency alignment that required adjudication.

RECOMMENDATIONS

1. **Plan bearing replacement** at the next available maintenance window. The machine is operating in the danger band with a confirmed outer-race defect frequency and harmonic; continued operation without intervention carries an elevated risk of accelerated damage progression.
2. **Monitor closely until replacement.** Given the severity level, increase monitoring frequency on this asset. Any further rise in overall vibration level or the appearance of additional harmonics or sidebands should be treated as a trigger for expedited intervention.

RECOMMENDED FOLLOW-UP MEASUREMENTS

None — the available data resolved the diagnosis without further measurement.

LIMITATIONS & CONFIDENCE NOTES

- **Z-score anomaly detection was not run:** statistical anomaly detection requires a streaming baseline; a single-file analysis does not carry one, so this layer of detection was unavailable for this reading.
- **No trend data:** no historical reading series was supplied, so no regression trend was computed. The severity and fault status reflect this single reading only.
- **Data-quality warning:** the reading carried an iso_zone_elevated warning (see Data Quality). All findings should be read with that caveat in mind, though the spectral evidence supporting the BPFO diagnosis is strong on its own terms.
- **Cause identification is outside the scope of vibration analysis:** the fault family (BPFO) is identified; the underlying cause that produced the outer-race damage is not determinable from vibration data alone. Oil analysis, thermal measurement, and dismounted visual inspection are required to separate candidate causes — see the Possible Underlying Causes section below.

MACHINE & ANALYSIS PARAMETERS

### Machine details

| | |
|---|---|
| Machine | Synthetic Compressor 01 |
| Type | compressor |
| Location | — |
| Sensor / MAC | SYN-COMP-01 |
| ISO group / support | 2 / rigid |

| | |
|---|---|
| Running speed | 1800.0 rpm |
| Overall vibration | 5.20 mm/s (y-axis), ISO Zone D |
| Bearing | 6206 |

### Analysis parameters

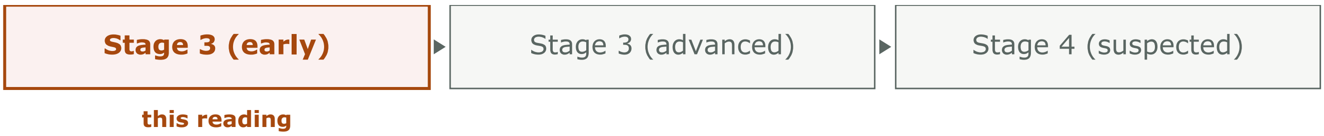
| | |
|---|---|
| Sample rate (fs) | 1000 Hz (from Fmax 500 Hz) |
| Spectral lines (N) | 2000 |
| Line spacing (Δf) | 0.250 Hz |
| Fmax | 500.0 Hz |
| Window | not recorded on this path |
| Spectrum type | Envelope spectrum |
| Detection | peak-pick against computed fault frequencies (pdm_core Layer 5) |
| Spectrum amplitude units | as supplied at upload (see conversion note) |
| Severity units | mm/s RMS (ISO 20816-3) |
| Threshold profile | route |
| Threshold source | iso_20816_3 — ISO 20816-3:2022 — Group 2, rigid support |
| Match tolerance | ±3% |
| Amplitude floor | 12.73× spectrum mean |
| Running speed | 1800 rpm (30.00 Hz shaft rate) |

DAMAGE STAGE ESTIMATE

### Stage 3 (early) — bearing_outer_race

- Committed fault: bearing_outer_race at 107.25 Hz
- Harmonic orders on the strongest axis: 1
- Shaft-rate sidebands detected: 0
- ISO zone at the time of measurement: D

A discrete defect frequency is the earliest damage standard vibration monitoring can resolve; early-stage detection requires HF/ultrasonic trending, so anything earlier than this could not have been seen and its absence is not evidence of a healthy bearing.




The damage-stage ladder this analysis uses, with the committed stage marked. Stages earlier than the first rung are not drawn because the method cannot resolve them — which is what the note above says in words.

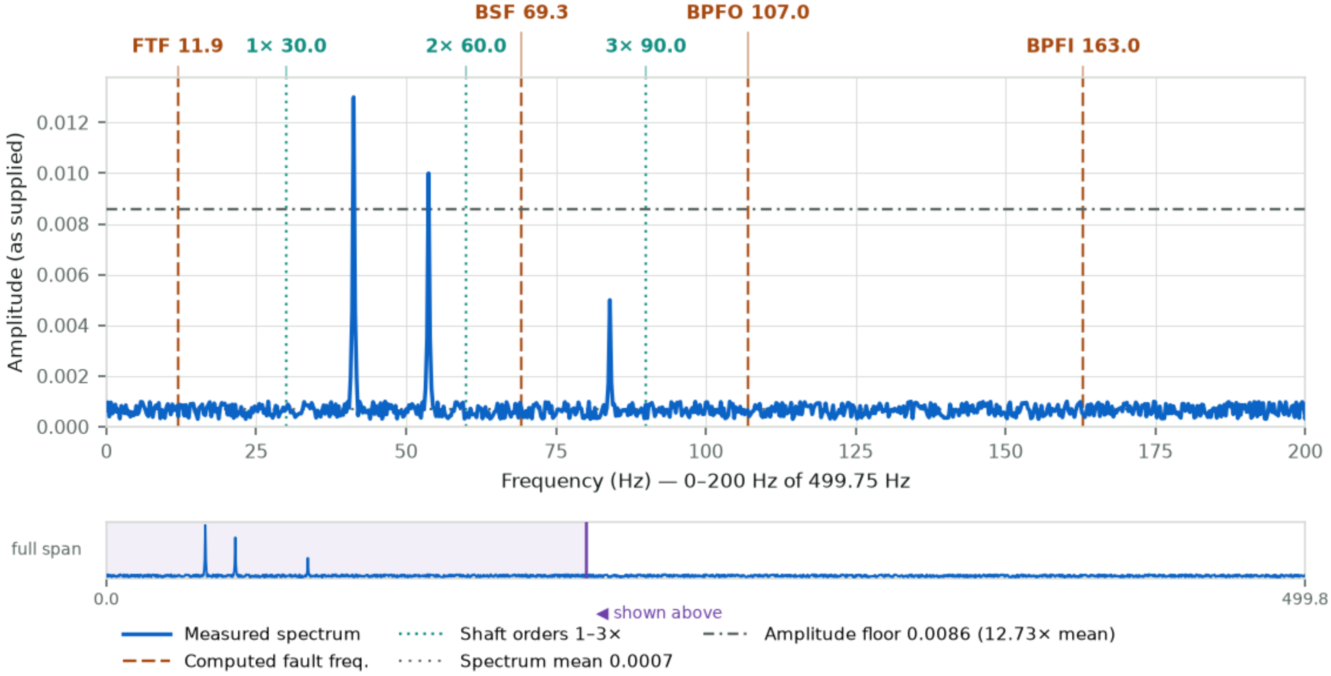
SPECTRAL EVIDENCE

Figures are rendered from the same computed values as the findings above — the measured spectrum, the shaft orders at the measured running speed, the bearing fault frequencies where a geometry was supplied, the peaks the analysis matched, and the amplitude floor from the active threshold profile. No figure introduces a number that is not already in this report.

## Envelope spectrum — X (axial)

Channel: **X (axial)** Overall: **0.50 mm/s** RMS: **not measured** Speed: **1800 rpm**

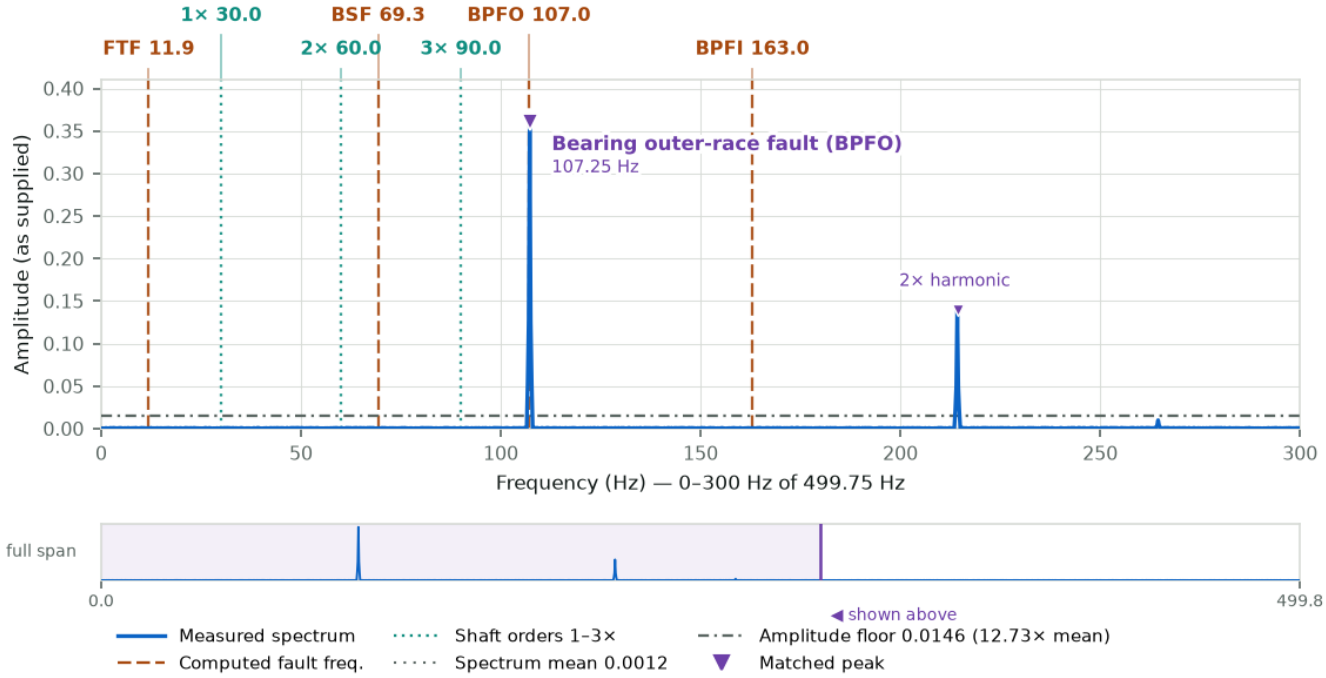
Spectrum: **Envelope spectrum** Δf: **0.250 Hz** Lines: **2000** Date: **2026-08-26T06:37:45**



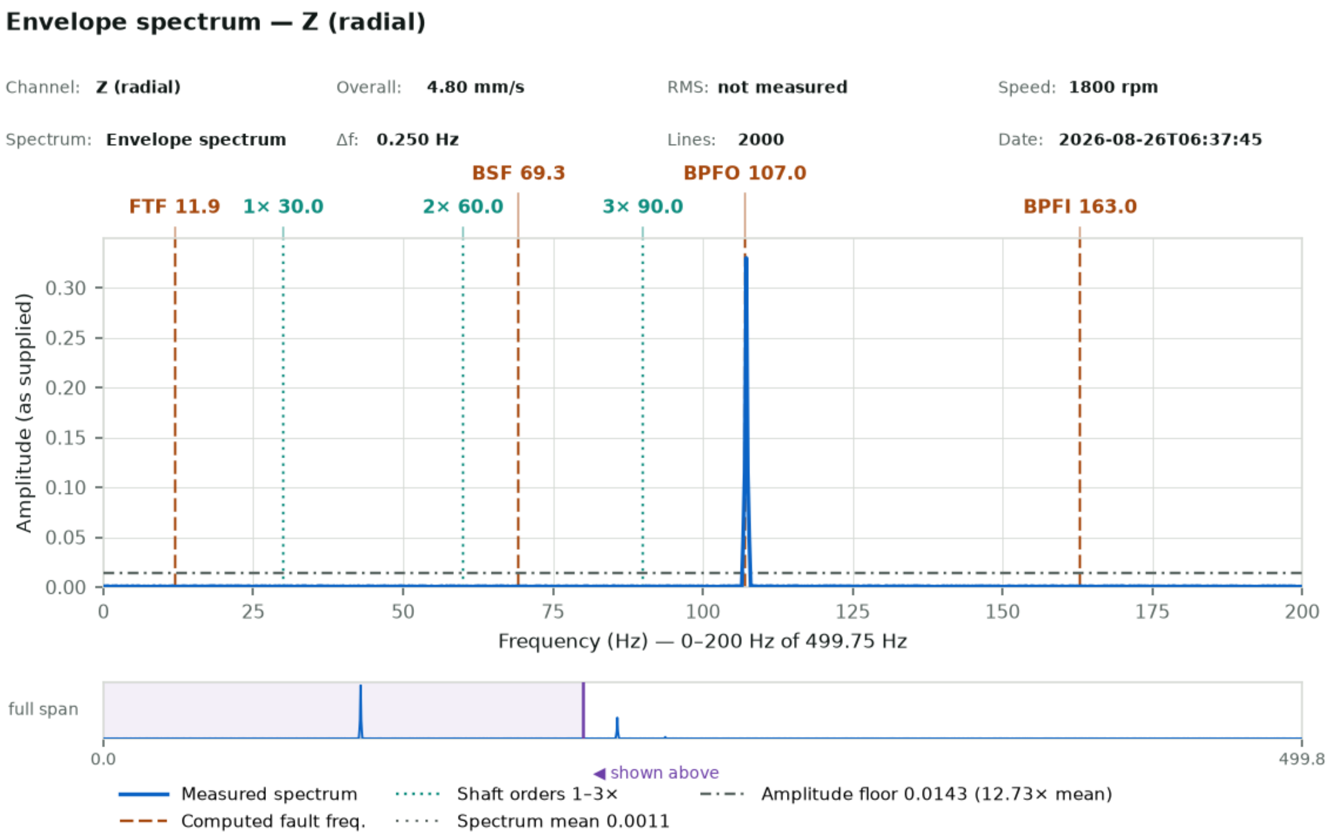

Envelope spectrum, X axis. No peak on this channel matched a computed fault frequency within tolerance.

## Envelope spectrum — Y (radial)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Channel: | Y (radial) | Overall: | 5.20 mm/s | RMS: | not measured | Speed: | 1800 rpm |
| Spectrum: | Envelope spectrum | Δf: | 0.250 Hz | Lines: | 2000 | Date: | 2026-08-26T06:37:45 |




Envelope spectrum, Y axis. Matched: bearing outer race at 107.2 Hz.




Envelope spectrum, Z axis. No peak on this channel matched a computed fault frequency within tolerance.

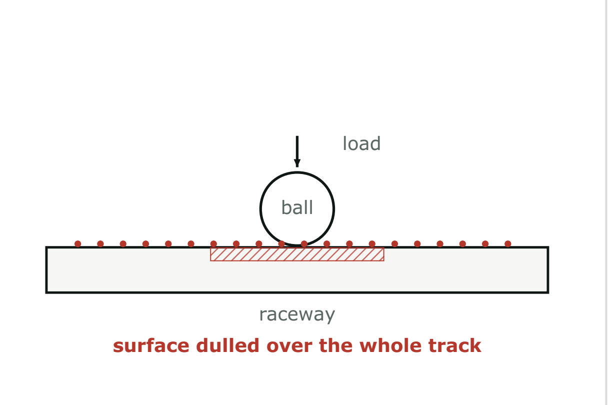
## POSSIBLE UNDERLYING CAUSES — HYPOTHESES FOR ANALYST CONFIRMATION

**These are hypotheses, not findings.** The analysis committed Bearing outer-race fault (BPFO) from the measured spectrum. What follows is the operator-approved list of causes known to produce that fault, in the reference library's own order — **none of them is confirmed by this measurement, and this analysis did not perform the inspection that would settle any of them.** A vibration reading identifies the fault; it does not identify what caused it. Each entry below names the evidence that would confirm or exclude it, split by who can collect it.

"Checked by this analysis" means the pipeline assessed evidence of that kind in the reading it was given — not that a measurement was taken specifically to test that cause. Bracketed references resolve against `references/INDEX.md`. `[inferred]` marks an observation that is our own reasoning rather than something a cited source states.

## 01 Solid contaminant ingress past a failed or inadequate seal

Hard particles of roughly the oil-film thickness enter the rolling contact and abrade the raceway, roughening a surface whose whole function is to stay smooth. The roughened track then loses its lubricant film locally, so abrasive wear develops into surface distress and eventually spalling. [#01 §5 Damage and actions, Abrasive wear, pp.66-67] [#02 Wear - Abrasive Contamination, p.7] [#04 Abrasive Wear, pp.5-6]




Schematic illustration — not derived from your data.

**Checked by this analysis — vibration evidence the pipeline evaluated:**

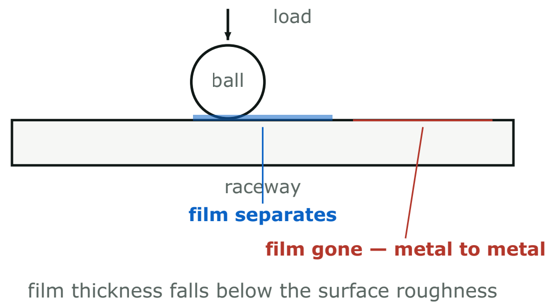
- Broadband rise across the spectrum without a clean BPFO series, since distributed roughening is not a single repeating impact.
  [inferred]

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- A matt, dulled or lapped-in raceway track rather than a discrete pit, with parallel furrows in the direction of motion where the particles are coarser than the lubricant film. How to collect: Dismounted inspection of the raceway under low magnification, in raking light.
  [#04 Abrasive Wear, pp.5-6] [#01 §5 Damage and actions, Abrasive wear, p.66]
- Wear spread around the circumference of the stationary ring rather than concentrated in one arc. Weak on its own, and arguably contradicted by our own source - #01 p.67 shows a STATIONARY inner ring carrying two localised wear zones - so distribution does not separate contamination from creep. How to collect: Map the wear extent against the recorded ring orientation before cleaning.
  [inferred]
- Rising ferrous particle counts and cutting/abrasive particle morphology in the lubricant before any discrete defect tone appears. How to collect: Oil sample from the return line or reservoir mid-level, with particle count and analytical ferrography.
  [inferred]

## 02 Lubricant film too thin to separate the rolling contact

When the film thins to a boundary or mixed regime the asperities touch, and repeated contact raises microcracks at the surface rather than below it. Those cracks propagate into micropitting and then spalling, so the damage is surface-initiated rather than a material-life limit. [#01 §5 Damage and actions, Surface initiated fatigue, pp.64-65] [#02 Inadequate Lubrication, pp.10-11] [#03 §1.3 Urgency of bearing exchange, PDF p.8 = printed p.7 (/2 ED)]



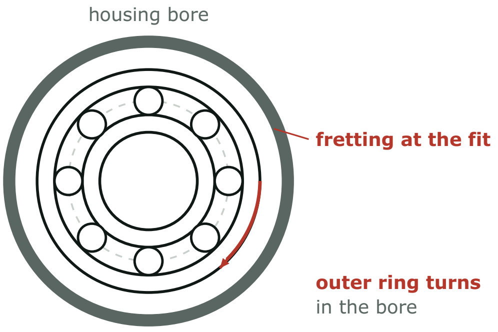

Schematic illustration — not derived from your data.

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Bearing temperature climbing and failing to settle at a steady state in stationary operation. #03 reports temperature as the reliable indicator of a lubricant-supply fault and, in its own stopped-lubrication test, the shock value as the less sensitive of the two; that is a claim about that comparison, not a general ranking of thermal over vibration. How to collect: Thermocouple at the bearing housing, trended over a run-up to steady state rather than spot-read. [#03 §1.2.1 Wide-spread damage, PDF p.6 = printed p.5 (/2 ED)] [#03 §1.3 Urgency of bearing exchange, PDF p.8 = printed p.7 (/2 ED)]
- Dull, lustreless or frosted raceway over a broad area rather than a discrete pit, sometimes with heat discolouration. How to collect: Dismounted inspection; note discolouration separately from wear. [#01 §4 ISO failure modes classification, Surface initiated fatigue, p.44] [#01 §8 Appendices, glossary entry Frosting, p.100] [#02 Inadequate Lubrication, Level 1 - Discoloration, p.10]
- Abraded matter measurable in the lubricant, which #03 lists as a lab route to bearing condition alongside temperature and vibration. How to collect: Oil sample sent for wear-debris measurement, kept as a trend rather than a single reading. [#03 §1.2.1, Measuring abraded matter in lubricant, PDF p.6 = printed p.5 (/2 ED)]
- Viscosity out of grade, or additive depletion, in the lubricant serving that bearing. How to collect: Oil sample with viscosity at 40 C and an additive-element scan. [inferred]

## 03 Housing fit inadequate for the load condition, letting the outer ring creep

An outer ring that is not held firmly enough for the direction and rotation of the load turns slowly in its housing instead of staying put. The relative movement polishes and wears the outside surface and shifts the load zone, so the raceway damage no longer sits where the applied load says it should. [#01 §2 Inspection and troubleshooting, Table 2 solution code 31, p.24] [#01 §5 Damage and actions, Abrasive wear, p.67, bottom-left caption] [#03 §2.1 Determination of operating data, PDF p.10 = printed p.9 (/2 ED)]




the ring slips instead of gripping — the fit frets away

Schematic illustration — not derived from your data.

**Checked by this analysis — vibration evidence the pipeline evaluated:**

- Rising broadband noise and vibration level with no matching change in the fault-frequency evidence. #01 gives raised noise and vibration as a consequence of ring creep, so this is a corroborating level symptom, not a frequency signature.
  [#01 §2 Inspection and troubleshooting, Table 2 solution code 31, p.24]

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Polishing wear, or adhesive wear marks, on the ring outside diameter - damage outside the rolling contact entirely. The appearance is not fixed to one wear mode, so an unmarked OD is the negative finding, not a particular finish. How to collect: Inspect the ring OD at dismounting, before cleaning it.
  [#01 §5 Damage and actions, Abrasive wear, p.67, bottom-left caption] [#01 §5 Damage and actions, Adhesive wear, p.68, top-right caption]
- Matching polishing or fretting on the HOUSING BORE itself, not only on the ring. How to collect: Inspect the housing bore at dismounting, before cleaning it.
  [inferred]
- A load-zone mark that has migrated, or two wear zones on one OUTER ring, rather than a single arc consistent with the applied load direction. #01 documents that two-zone pattern for a creeping INNER ring; the outer-ring analogue is ours. How to collect: Record the ring orientation relative to the load before removal, then map the wear arc against it.
  [inferred]
- Which ring rotates and whether the load is point or circumferential, recorded as operating data before any diagnosis is attempted. How to collect: Machine records - rotating ring, load direction, whether load is constant, alternating or oscillating.
  [#03 §2.1 Determination of operating data, PDF p.10 = printed p.9 (/2 ED)]

- A rotating outer ring load, or a history of shaft unbalance. #01 names unbalance as a cause of outer-ring creep even where the fits were originally correct, which gives this cause a machine-side antecedent the vibration path can detect on its own. How to collect: Balance records and 1x amplitude history for the machine, alongside the seat measurements.
  [#01 §2 Inspection and troubleshooting, Table 2 solution code 31, p.24]

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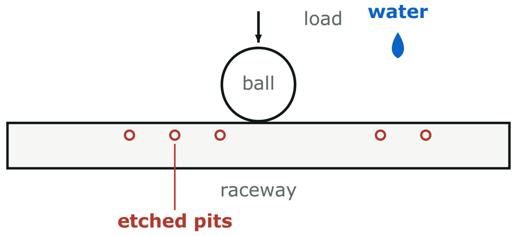
## 04 Water or condensate reaching the raceway

Water in the bearing attacks the finished steel surface chemically, with no metal-to-metal contact required, and etches or pits it. The pits then act as stress raisers under rolling contact, so a corrosion problem presents later as a fatigue one. [#02 Etching - Corrosion, p.9] [#04 Corrosion, pp.7-8]




standing water etches the steel between rolling contacts

Schematic illustration — not derived from your data.

> COLOUR IS NOT A DISCRIMINATOR HERE. #04 p.8 assigns the reddish-brown oxide colour to FRETTING corrosion - rust without water being present - which is this entry's nearest differential. The colour was removed from the visual observation in R2-B0.2 for exactly that reason; use the pit pattern and its position, not the tint.

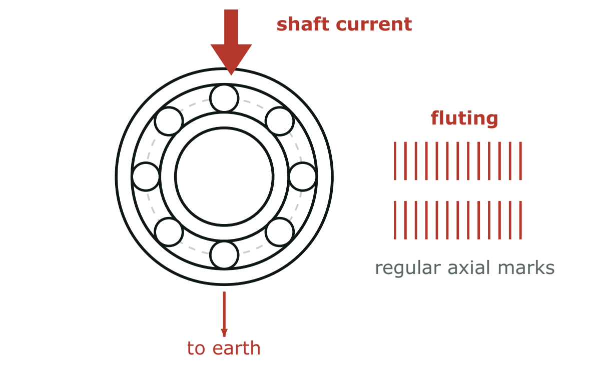
**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Staining or pitting on the raceway, in an even and uniform pattern where standing water did the work, and confined to the LOWER portion of the component where water was left undrained in the sump. How to collect: Dismounted inspection with the component's installed orientation recorded, since the localisation is the discriminator.
  [#04 Corrosion, p.7] [#02 Etching - Corrosion, p.9, figs. 12 and 16]
- Whether the staining polishes out. This is a disposition boundary, not just a description - staining that cleans up with fine emery or crocus cloth permits reuse, pits that will not clean up condemn the bearing. How to collect: Light polish of a stained area with fine emery or crocus cloth, then re-inspect for surviving pits.
  [#02 Etching - Corrosion, p.9, fig. 12]
- Present without recent running. Static corrosion appears in storage or after improper washing and drying at a previous inspection, before the bearing is ever mounted. How to collect: Establish from the maintenance record whether the bearing was washed, dried and stored between inspections, and in what packaging.
  [#02 Etching - Corrosion, p.9]
- Free or standing water in the lubricant, including water left undrained in the sump. How to collect: Oil sample and a sump low-point drain check, taken before the system is topped up or flushed.
  [#04 Corrosion, p.7] [#02 Etching - Corrosion, p.9]

- A moisture level above the component-type limit, reported as dissolved, emulsified or free rather than as a single number. Neither cited document gives a concentration limit or uses the emulsified/dissolved split - this needs a lab limit bulletin from the library before it can be relied on. How to collect: Oil sample analysed for water content, reported as dissolved, emulsified or free rather than a single number.
  [inferred]
- Temperature changes across the bearing housing, which drive the condensate that collects inside it. How to collect: Housing temperature record, or the ambient and duty record that stands in for it.
  [#02 Etching - Corrosion, p.9]
- Repeated stop-start duty, or large ambient swings, as the specific driver of those temperature changes. #02 says only temperature changes, unqualified. How to collect: Operating log - run pattern, ambient range, washdown or humidity exposure.
  [inferred]

## 05 Stray shaft current passing through the bearing to earth

Current crossing the lubricant film discharges through the contact and melts microscopic craters in the raceway. Continuous low-level leakage produces closely spaced craters that develop into axial fluting, while a high-energy discharge produces isolated deep pits. [#01 §4 ISO failure modes classification, Electrical erosion, pp.53-54] [#01 §5 Damage and actions, Excessive current erosion and Current leakage erosion, pp.74-76] [#04 Electrical Erosion, pp.9-10] [#02 Burns from Electric Current, p.21] [#43 Table 4-5 Cause of Motor Bearing Failure, p.4-15 (PDF page 45)]



current crosses the contact and pits both surfaces

Schematic illustration — not derived from your data.

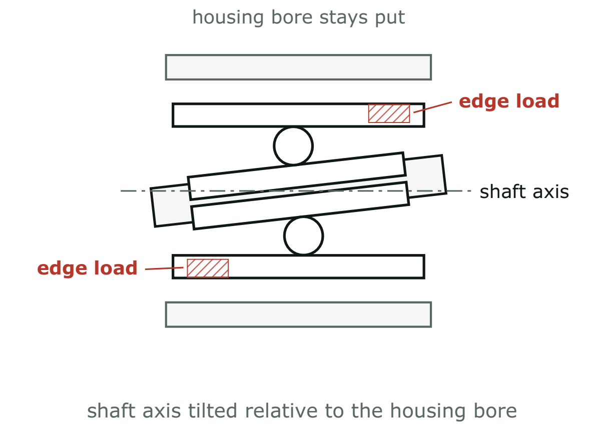
**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Regular fluting running parallel to the rolling axis, presenting as a staged progression - a dull grey zone with small shallow craters, then early fluting, then advanced fluting. How to collect: Dismounted inspection of the raceway across its width, in raking light.
  [#01 §4 ISO failure modes classification, Electrical erosion, pp.53-54] [#01 §5 Damage and actions, Current leakage erosion, pp.75-76] [#02 Burns from Electric Current, p.21, fig. 62]
- Flute PITCH, not the presence of flutes. Fluting is not electrically exclusive - #01's own glossary gives washboarding as mechanical periodic transverse wear associated with abrasive wear in lightly loaded bearings, used interchangeably with fluting but usually more widely spaced. How to collect: Measure the mark pitch across the raceway rather than recording only that periodic marks are present.
  [#01 Appendix E, glossary entry Washboarding, p.103]

- Craters massed in a bead-like or zig-zag formation rather than distributed as a flute, which #01 attributes to excessive current as distinct from continuous leakage. How to collect: Inspect rollers and raceway under magnification and record the crater pattern, not just its presence.
  [#01 §5 Damage and actions, Excessive current erosion, p.74]
- Arc pitting or small burns where the machine was STATIONARY, versus axial fluting where it was ROTATING while current passed. How to collect: Establish whether the suspected current event (welding, drive fault) coincided with rotation or standstill.
  [#02 Burns from Electric Current, p.21, figs. 60 and 62]
- Crater spacing corresponding to the rolling element spacing. Attributed to #04 only; #01 pp.74-75 describes bead-like and zig-zag formations and does not make this claim. It is also NOT specific on its own - the same sources give element-pitch spacing for true brinelling (#04 p.10) and false brinelling (#01 p.73), so treat it as the weakest of the visual cues. How to collect: Measure the pit pitch and compare it with the rolling element pitch for that bearing.
  [inferred]
- Presence of a variable-speed drive, recent welding on the machine, or degraded earthing/grounding connections. #01's case study is the caution worth carrying - an insulated bearing on a frequency-converter motor still failed by current leakage after a repair left the earth cable disconnected, so fitted insulation is not itself the answer. How to collect: Electrical installation record - drive type, earthing brush and earth cable condition, insulated bearing fitted or not, welding history.
  [#01 §7 Case studies, Variable speed electric motor problem, pp.88-89] [#02 Burns from Electric Current, p.21] [#04 Electrical Erosion, p.9]

## 06 Shaft or seat misalignment concentrating load at the raceway edge

Misalignment tilts the rolling path so the load is carried on an edge instead of across the intended contact width, raising local stress well above design. Fatigue then appears on one side of the raceway only, or as two opposed load zones on a double-row bearing. [#01 §5 Damage and actions, Subsurface initiated fatigue, p.63, third caption] [#01 §5 Damage and actions, Surface initiated fatigue, p.65, bottom-left caption] [#02 Misalignment and Inaccurate Seat and Shoulder Machining, p.14] [#43 Table 4-5 Cause of Motor Bearing Failure, p.4-15 (PDF page 45)]



Schematic illustration — not derived from your data.

TWO COLLISIONS. (1) Both this and inner_race_excessive_axial_load can present as an axially offset load mark. Misalignment tilts the path; axial overload shifts it while keeping it square. Decide on the alignment record and the thrust arrangement, not on the mark alone. (2) Two load zones 180 degrees apart is shared with outer_race_oval_clamping_overload - #01 gives that signature for an out-of-round seat at least as prominently. The discriminator is ring identity: a DOUBLE-ROW INNER ring points here, a stationary OUTER ring points to oval clamping.

**Checked by this analysis — vibration evidence the pipeline evaluated:**

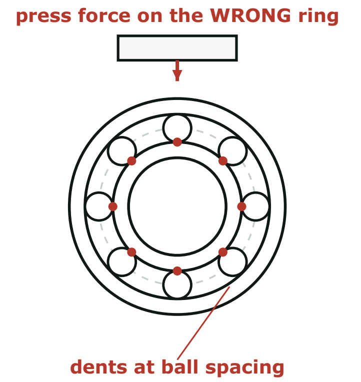
- Elevated axial vibration relative to radial at running speed on the same machine, which is the misalignment signature the detectors already use.
  [inferred]

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Spalling or a load mark confined to one side of the raceway width, rather than centred across it. How to collect: Dismounted inspection with the load-zone position recorded before cleaning.
  [#01 §5 Damage and actions, Subsurface initiated fatigue, p.63, third caption] [#02 Misalignment and Inaccurate Seat and Shoulder Machining, p.14]
- Two load zones 180 degrees apart on a DOUBLE-ROW bearing's inner ring. The ring identity is the discriminator - see the collision note. How to collect: Map both load zones and record which ring carries them before cleaning.
  [#01 §5 Damage and actions, Surface initiated fatigue, p.65, bottom-left caption]
- Alignment record, shim history and soft-foot check for the machine train. How to collect: Last alignment report and any change of coupling, baseplate or foundation since.
  [#01 §2 Inspection and troubleshooting, Table 2 solution codes 15 and 19-20, pp.19-21] [#02 Misalignment and Inaccurate Seat and Shoulder Machining, p.14]

## 07 Impact during mounting, transmitted through the rolling elements

Driving a bearing onto a shaft by striking it forces the mounting load through the rolling elements instead of the ring being pressed, denting the raceway at each element position. The dents are permanent deformation rather than wear, and their raised edges later seed surface fatigue. [#01 §5 Damage and actions, Surface initiated fatigue, p.65, bottom-right caption] [#04 Plastic Deformation, p.10] [#02 Handling and Installation Damage, p.15, figs. 41 and 42]




the force crosses the rolling elements and prints them

Schematic illustration — not derived from your data.

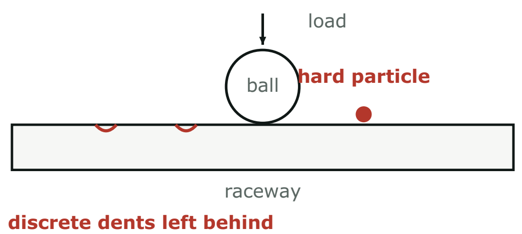
**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Dents, or later spalls, spaced at exactly the rolling element pitch. How to collect: Measure the mark pitch and compare it with the rolling element pitch; equality is close to conclusive.
  [#04 Plastic Deformation, Overload or true brinelling, p.10] [#01 §5 Damage and actions, Surface initiated fatigue, p.65, bottom-right caption] [#02 Handling and Installation Damage, p.15, fig. 42]

- The bearing was STATIONARY when the load was applied, so the marks record the element positions at that one moment; a rotating bearing cannot reproduce that pattern because its elements do not hold station. The sources give the pitch-exact pattern but never state this reasoning. How to collect: Establish from the maintenance record whether an impact event occurred with the machine stopped.
  [inferred]
- STAGE-DEPENDENT SIGNATURE. Fresh dents early, spalls at element spacing later - #01's own exemplar for this cause sits under Surface initiated fatigue and shows spalls, not dents, so an inspection that finds no dents does not clear mounting impact. How to collect: Record whether the marks are unbroken depressions or broken-out spalls, and read that as stage rather than as a different cause.
  [#01 §5 Damage and actions, Surface initiated fatigue, p.65] [#04 Plastic Deformation, p.10]
- Machining marks still visible in the bottom of the dent, showing metal flow rather than material removal. How to collect: Inspect a dent under magnification for surviving original finish.
  [#04 Plastic Deformation, p.10]
- A raised lip or raised edges around the dent, which is what makes a mounting dent a future fatigue site rather than a cosmetic mark. How to collect: Inspect the dent rim under magnification, and record it separately from the dent itself.
  [#04 Plastic Deformation, p.10] [#02 Handling and Installation Damage, p.15, fig. 42]
- Roughness, vibration and noise reported immediately after an installation, rather than as a gradual change. How to collect: Compare the first post-maintenance vibration reading with the pre-removal baseline.
  [#02 Handling and Installation Damage, p.15]
- Time-since-intervention used as the discriminator - damage present from the first run after work, rather than developing over time. No cited page frames it that way or contrasts it with gradual development. How to collect: Line the damage up against the maintenance dates, not only against running hours.
  [inferred]

## 08 Hard debris over-rolled between element and raceway

A particle trapped in the contact is rolled over and pressed into the surface, leaving a round-bottomed dent with a raised rim rather than removing material. The rim concentrates stress on subsequent passes, so a contamination event becomes a fatigue initiation site. [#02 Wear - Pitting and Bruising, p.8] [#04 Plastic Deformation, Indentation from debris, p.10] [#01 §5 Damage and actions, Indentations from particles, pp.79-80]




one over-rolled particle leaves a dent, not a wear track

Schematic illustration — not derived from your data.

**Checked by this analysis — vibration evidence the pipeline evaluated:**

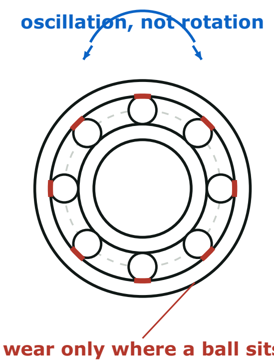
- A BSF-matched carrier rather than BPFO or BPFI. Sidebands alone do NOT point to a rolling-element fault: the detector adds +/-1x shaft sidebands to every committed bearing family alike, so the specificity is in which fault frequency the carrier matches, not in the presence of modulation. [inferred]

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Round-bottomed dents with a raised lip, where the raised metal acts as a surface-stress riser rather than as material loss. How to collect: Inspect elements and raceway under magnification, recording the dent profile and its rim. [#04 Plastic Deformation, Indentation from debris, p.10] [#02 Wear - Pitting and Bruising, p.8]
- Dents distributed WITHOUT regular spacing. The contrast is ours and the attribution needs care: #04 p.10 assigns the exact-roller-spacing dent series to Overload / true brinelling, and defines Indentation from handling as a separate subcategory with no spacing pattern at all. How to collect: Record whether dent spacing is regular or random, and compare any regular pitch with the rolling element pitch. [inferred]
- Metal chips or large particles of dirt in the lubricant, and a source for them - wear from gears, splines, seals, clutches, brakes or joints, an improperly cleaned housing, or a damaged or spalled component elsewhere. How to collect: Filter residue and magnetic plug inspection alongside a particle count, kept as history rather than a single reading. [#02 Wear - Pitting and Bruising, p.8]
- Angular particle morphology specifically. No cited page describes particle SHAPE; the sources speak only of size and origin. How to collect: Analytical ferrography reporting particle morphology, not a particle count alone. [inferred]

## 09 Vibration or oscillation while the bearing is stationary

A bearing that is not turning still carries its load on a few elements, and external vibration makes each element rub a few microns back and forth on the same spot. That repeated micro-movement wears the surface away where a static load alone would have left it untouched. [#01 §4 ISO failure modes classification, Frictional corrosion - False brinelling, p.52] [#01 §5 Damage and actions, False brinelling, p.73] [#01 §2 Inspection and troubleshooting, Table 2 condition 36, p.26]




a bearing that never turns still wears, at ball spacing

Schematic illustration — not derived from your data.

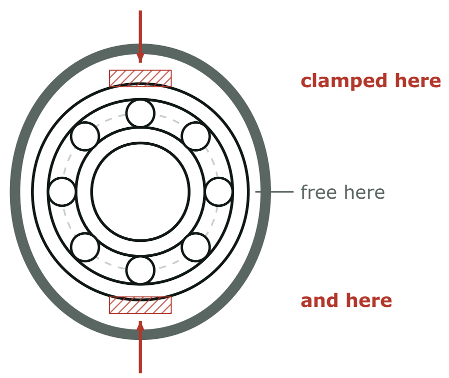
[#02 False Brinelling, p.20, with Brinell and Impact Damage, p.19]

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Marks at the rolling element spacing, in the loaded zone, worn TRANSVERSELY across the race width by slight AXIAL movement of the element rather than merely sitting on one spot. How to collect: Measure the mark pitch against the rolling element pitch, and record the mark's orientation across the race width. [#01 §4 ISO failure modes classification, Frictional corrosion - False brinelling, p.52] [#01 §2 Inspection and troubleshooting, Table 2 condition 36, p.26] [#02 False Brinelling, p.20, and fig. 59]
- THE DISCRIMINATOR against mounting impact - the original surface texture is WORN AWAY in a false-brinell mark, whereas a true brinell dent is deformation and still shows the grinding marks in its bottom. How to collect: Inspect the bottom of a mark under magnification and record whether the machining finish survives in it. [#02 False Brinelling, p.20, with Brinell and Impact Damage, p.19]
- Mark SHAPE follows the element - sphered depressions in ball bearings, longitudinal depressions in roller bearings - and parallel flutes rather than discrete depressions mean it happened while ROTATING, which is a different condition. How to collect: Record the depression shape and whether the marks are discrete or continuous flutes, alongside the pitch. [#01 §4 ISO failure modes classification, Frictional corrosion - False brinelling, p.52]
- A standby, spared or seasonally idle duty, a period of road, rail or sea transport, or a machine left standing beside running plant. How to collect: Operating log covering idle periods, transport, and whether nearby plant ran while this machine stood. [#01 §2 Inspection and troubleshooting, Table 2 condition 36, p.26] [#01 §5 Damage and actions, False brinelling, p.73, Actions] [#02 False Brinelling, p.20]
- The mark pitch is the SAME signature as mounting impact, from a different event. No cited page states that mounting-impact brinell marks fall at rolling element pitch - the claim leans on the sibling entry, not on this entry's own sources. How to collect: Read the pitch alongside the surface-texture test above, which is the clause that actually separates the two. [inferred]

## 10 Housing distortion clamping the outer ring oval

A housing bored or bolted out of round squeezes the outer ring into an oval, creating two diametrically opposed high-load regions where the design intended one. Fatigue then appears as spalling roughly 180 degrees apart rather than in a single load arc. [#01 §3 Path patterns, Inner ring rotation - oval clamping of the stationary outer ring, p.37] [#01 §2 Inspection and troubleshooting, Table 2 solution code 15, p.19]




an out-of-round bore pinches the ring on one diameter

[#01 §5 Damage and actions, Subsurface initiated fatigue, p.63, bottom-right caption]

Schematic illustration — not derived from your data.

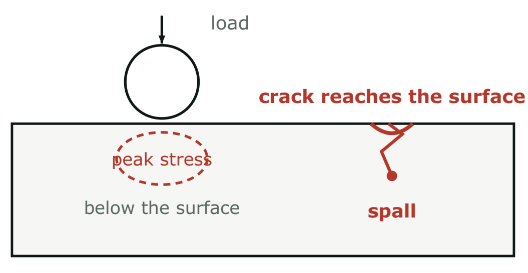
RING IDENTITY. Two opposed load zones 180 degrees apart is NOT specific to oval clamping - #01 gives the same signature for excessive misalignment on a double-row bearing. The discriminator visible in the source is which ring carries it: the OUTER ring points here, a double-row INNER ring points to inner_race_misalignment_edge_loading.

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- Two - occasionally more - opposed load zones or spalled regions roughly 180 degrees apart on a STATIONARY outer ring, where the applied radial load is unidirectional and constant on the rotating inner ring. How to collect: Map the spall or path-pattern positions against the recorded ring orientation before cleaning.
  [#01 §3 Path patterns, Inner ring rotation - oval clamping of the stationary outer ring, p.37, fig. 16] [#01 §5 Damage and actions, Subsurface initiated fatigue, p.63, bottom-right caption]
- Housing bore out of round, and the bearing seat out of round, on measurement. How to collect: Bore gauge at several angular positions with the bearing removed.
  [#01 §2 Inspection and troubleshooting, Table 2 solution code 15 Bearing seat is out-of-round, p.19]
- Measured COLD AND UNLOADED. A real practitioner convention, but #01 gives only the instruction to check the seats for roundness and states no temperature or load state for the measurement. How to collect: Take the bore readings with the machine at ambient and the bearing removed, not after a run.
  [inferred]
- Operating temperature elevated against the machine's own history or its sister units, from the reduced clearance or preload that pinching produces. Checkable in service, without dismounting. How to collect: Bearing-housing temperature trended and compared against an identical unit on the same duty.
  [#01 §2 Inspection and troubleshooting, Table 2 solution code 15, p.19] [#01 §3 Path patterns, p.37]
- Whether the housing is bolted to a flat surface, whether shims cover the whole housing base, and whether a split housing's two halves fit concentrically. These are the source's own named reasons and are cheap field checks, unlike the spall pattern. How to collect: Inspect the mounting surface, shim coverage and split-line fit at the machine before dismounting anything.
  [#01 §3 Path patterns, p.37] [#01 §2 Inspection and troubleshooting, Table 2 solution code 15, p.19]

## 11 Subsurface fatigue reaching the surface at the end of rating life

Repeated stress cycles nucleate cracks at inclusions below the contact surface, and those cracks grow until a piece of the surface detaches. This is the mechanism the bearing rating life describes, so it is the one cause on this list that is not a defect in installation or operation. [#01 §5 Damage and actions, Subsurface initiated fatigue, p.63] [#04 Subsurface Fatigue, p.3] [#04 Surface-initiated Fatigue, p.4]




the crack starts where the stress is highest — under the skin

Schematic illustration — not derived from your data.

> LAST. Weigh every other cause in this batch before this one. It is the only entry that concludes nothing was done wrong, so reaching it early ends the investigation that the other thirteen entries exist to run. #04 p.3 puts a number on the prior: subsurface fatigue is not a common issue where better quality metals are used, and most bearings will fail by another mechanism first.

**Evidence to collect — analyst fieldwork; not performed by this analysis:**

- A spall with NO contamination-dent and NO handling signature anywhere on the bearing - the two competing surface-damage sources the source names explicitly. How to collect: Full dismounted inspection covering the competing damage categories before attributing anything to normal fatigue.
  [#04 Surface-initiated Fatigue, p.4] [#04 Subsurface Fatigue, p.3]
- And no CORROSION or ELECTRICAL signature either. Those two exclusions are on neither cited page; they are ours, carried over from the six-category taxonomy rather than from a statement in the sources. How to collect: Inspect for etching, staining, craters and fluting as part of the same dismounted pass.
  [inferred]
- Achieved running hours compared against the calculated rating life for the ACTUAL duty, not the design duty. Read this as WEAK positive evidence only: L10 is the point at which 10 percent of a set of identical bearings have failed, not an expiry date, so reaching it leaves 90 percent expected still running - and failing well short of it argues actively against this cause. How to collect: Operating hours, load history and any duty change since commissioning, with the rating life recalculated for the duty actually run.
  [#04 Subsurface Fatigue, p.3] [#01 §5 Damage and actions, Subsurface initiated fatigue, p.63, Actions bullet 1]

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never does arithmetic. On the drafted path the narrative is written by a model
and then re-checked against the computed result before issue: the title line, the
ISO zone language, the fault terms, the confidence binding, every quoted number,
the damage-stage language, the cause language and the structured echo. A draft
that fails any check is refused, and the job degrades to the deterministic report
with a visible note rather than issuing unchecked prose.
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